UCRL-TB-117598-16

Precision Vacuum Casting of Metals

Technology for producing near-net-shape metal parts can reduce waste and costs

LLNL is developing precision vacuum casting as a way to reduce metal waste. This technology could have applications in environmentally responsible private-sector manufacturing by reducing waste and the cost of waste disposal.

Modern vacuum foundry plus computational capability

We have both a modern vacuum foundry and the capability to computationally simulate the fluid flow, heat transfer, and solidification behavior of the casting process. By combining simulations with actual casting experience, we can optimize the mold fill for complex, near-net-shape castings with a minimum number of design iterations. Because the parts require little machining, waste in the form of turnings and chips is dramatically reduced compared to other fabrication methods.

The centerpiece of our foundry is a 0.9-m x 0.9-m x 1.5-m vacuum chamber, equipped with two radio-frequency power supplies to heat the melt crucible and mold separately. At room temperature, the vacuum in the chamber is approximately 10^{-6} to 10^{-7} Torr, but at pour temperatures of 1350°C, it is typically 10^{-3} to 10^{-4} Torr. Molds may be fabricated from a variety of vacuum-compatible materials, such as graphite and refractory metals, that can be precision machined. We have extensive facilities for applying many different specialty coatings to protect crucible and mold surfaces and provide release for the finished part. A system to actively cool the mold is also being developed. An enclosed hood attached to the vacuum chamber facilitates the handling of mildly toxic or hazardous materials. Foundry operations are controlled by computer, and all diagnostic data can be electronically stored for later reference and comparison to simulations.

APPLICATIONS

- *Automotive parts*
- *Gas-turbine engine parts*
- *Precision-machinery manufacturing*
- *High-precision castings for the electronics industry*
- *Parts made from metals that require special handling*

Calculated fill of a flat-plate mold with liquid metal.

A powerful means of modeling

Casting-process simulations are conducted with a unique combination of commercial casting software (ProCAST) and LLNL-developed thermo-mechanical codes (NIKE, TOPAZ, GRIZ). The linking of these capabilities gives us an exceptionally powerful means of modeling not only the heat transfer and shrinkage deformation within a cast part, but also the dynamics of the mold filling. We can thus design molds that fill and cool in such a way as to mitigate the effects of shrinkage and promote a fast directional solidification, but still yield near-net-shape parts with acceptable metallurgical properties. The result of calculations can be validated directly with experiments in the foundry.

Availability: This technology is available now. We welcome industrial partners interested in developing and using it in the private sector.

Contacts

William H. Gourdin
Phone: (510) 422-8093
Fax: (510) 423-0740
E-mail: gourdin1@llnl.gov
Mail code: L-355

Peter J. Raboin
Phone: (510) 422-1583
Fax: (510) 422-2085
E-mail: raboin@trinity.llnl.gov
Mail code: L-122